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Emotion and Executive Dysfunction in Young Children with Disruptive Behavior Disorders: The Role of Cardiac Autonomic Balance

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Abstract

Objective. There is support for altered parasympathetic (PNS) and sympathetic (SNS) functioning among children with disruptive behavior disorders (DBD) which may underlie impairments in both emotion regulation (ER) and executive functioning (EF). This study examined the extent to which cardiac autonomic balance (CAB), a composite index that integrates the relative influences of the PNS and SNS on the heart, differentiates young typically developing (TD) children and those with a DBD.

Method. Participants included 245 young children (72% boys, $M_{\text{age}} = 5.44$ years; 82% Latinx; 50% TD). Indexes of PNS (i.e., respiratory sinus arrhythmia [RSA]) and sympathetic (i.e., pre-ejection period [PEP]) reactivity were collected during a baseline task along with six other lab tasks measuring ER and EF. CAB was computed using the following formula: $\text{CAB} = \text{RSA}_z - (-\text{PEP}_z)$ with higher positive scores reflective of greater reliance on PNS input.

Results: No difference in resting/baseline CAB was found among the groups. On the other hand, children with DBDs had *lower* and *negative* CAB *reactivity* scores across 4 out of the 6 tasks relative to the TD group which had positive CAB reactivity scores (Cohen's d range = -0.27 to -0.38).

Conclusions. Children with DBDs' negative CAB values indicate a physiological profile of greater SNS reactivity while children in the TD group's positive CAB values indicate a physiological profile of greater PNS reactivity. A lower and negative CAB reactivity profile may be a physiological indicator that contributes to underlying impairments in both EF and ER among children with DBD.

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Disclosures

The authors declare that they have no conflict of interest.

Keywords

disruptive behavior disorders; emotion regulation; executive function; cardiac autonomic balance; RSA; PEP; children

Externalizing behavior problems, typically represented by disruptive behavior disorder (DBD) diagnoses such as attention-deficit/hyperactivity disorder (ADHD), oppositional defiant disorder (ODD), and/or conduct disorder (CD), represent the most common reason for early childhood mental health referrals (Allen, 2015). The stability and significant impairment attributable to early DBD is well established (Barkley, 2002). In terms of its etiology, recent work has highlighted the heterogeneity among children with DBD in terms of deficits across self-regulation skills, including executive functioning (EF; Ogilvie et al., 2011) and emotion regulation (ER; Graziano & Garcia, 2016). Within the autonomic nervous system (ANS), there is support for altered parasympathetic (PNS) and sympathetic (SNS) functioning among children with DBD, which are linked to both ER and EF (Berntson et al., 2008; Musser et al., 2011; Musser et al., 2013).

PNS dysfunction has been linked to various disruptive behaviors ranging from aggression to ADHD symptoms (Beauchaine & Thayer, 2015; Porges, 1995). PNS linked cardiac activity is typically measured via respiratory sinus arrhythmia (RSA), a component of heart rate variability and marker of vagal influence over the heart (Porges, 2007). Resting or baseline conditions of RSA are thought to represent an organism's ability to maintain homeostasis and potential responsiveness to stress. In fact, a recent meta-analysis found lower resting RSA was related to greater emotion dysregulation within a clinical group of children and adolescents, which included children with ADHD (Bellato et al., 2024). While during rest the vagus nerve exerts an inhibitory influence on the heart and limits sympathetic influences, during challenging states, the vagal "brake" is disengaged resulting in decreases in PNS output to the sino-atrial (SA) node of the heart which contributes to an increase in heart rate (Porges et al., 1996). While it is context dependent, RSA withdrawal during challenging tasks is typically viewed as an adaptive self-regulatory response. Indeed, a meta-analysis of 44 studies ($n = 4996$ children) by Graziano and Derefinko (2013) found that greater levels of respiratory sinus arrhythmia (RSA) withdrawal were related to fewer externalizing behavior problems. On the other hand, RSA augmentation (an increase in RSA from rest during a challenge) is typically viewed as maladaptive (Beauchaine, 2012; Porges, 2007) and have been noted among children with ADHD (Musser et al., 2011; Tenenbaum et al., 2018; McQuade & Breaux, 2017; Feeney et al., 2023). Excessive RSA withdrawal in non-threatening situations may also be maladaptive and indicative of an exaggerated and unnecessary emotional response (Hastings et al., 2008). Indeed, some studies have found that children with ADHD experience greater RSA withdrawal during challenging tasks relative to typically developing (TD) children (Musser et al., 2018; Ward et al., 2015; Beauchaine et al., 2013).

More limited research has been done as it relates to the link between SNS reactivity, in particularly pre-ejection period (PEP), and DBD. PEP, the time elapsed between the electrical depolarization of the left ventricle and the opening of the aortic valve, is a

commonly used index of beta-adrenergic sympathetic influence over the heart (Newlin and Levenson, 1979; Kelsey, 2012). Decreases in the time between heart contractions result in shortening of PEP, which indexes an increase in SNS activation (Berntson et al., 1994). A shortening of PEP in response to incentives has been associated with conduct problems, aggression, and ADHD in preschoolers (Beauchaine et al., 2013; Crowell et al., 2006) and older children and adolescents (Beauchaine et al., 2007; Beauchaine et al., 2001). Most importantly, however, almost all PNS and SNS research studies comparing children with DBDs and TD children tend to examine RSA and PEP in isolation, despite the long-standing recognition that both may exert either antagonistic or synergistic influences on cardiac control (Beauchaine et al., 2011; Berntson et al., 1991).

The autonomic space model has emerged as a framework to understanding the multiple ways in which the PNS and SNS relate (Berntson et al., 2008). High resting heart rate may be a function of high SNS input or tone, low PNS input or tone, or both. SNS and PNS tones are situated orthogonally to each other and as such set the boundaries of autonomic space in terms of how a system may react to a challenging situation/demand (Berntson et al., 1994). Measurement of both SNS and PNS reactivity concurrently allows us to determine children's differential reliance on each system, both, or neither (Berntson et al., 1994). Such model proposes two ANS indices, cardiac autonomic balance (CAB) and cardiac autonomic regulation (CAR), that can more adequately quantify the relative influences of the SNS and PNS on heart rate (Berntson et al., 2008). As outlined by Berntson and colleagues (2008), CAB is calculated as $(zRSA - (-zPEP))$ with higher positive scores reflective of greater reliance on parasympathetic input. On the other hand, CAR is calculated as: $CAR = zRSA + (-zPEP)$ with higher positive scores indicating greater co-activation of SNS and PNS while negative scores indicating co-inhibition of SNS and PNS.

Most of the prior research on CAB has focused on its stability (CAB seems to achieve excellent stability by age 5; (Alkon et al., 2011), and on how it may predict internalizing symptoms in adults (Brush et al., 2019). Within pediatric samples, the few studies that have examined CAB have found it useful in predicting youth PTSD symptoms and internalizing symptomology (Cohen et al., 2020). Theoretically, Quigley and Moore (2018) review how the development of CAB in early childhood may be a pathway to various mental health outcomes, including disruptive behavior problems. Specifically, they argue that low SNS/high-PNS profiles of CAB serve as a path towards psychological health via increased emotion regulation and attentional control. In the case of children with externalizing behavior problems, diminished PNS tone occurs over time due to chronically engaging both systems (PNS and SNS) to handle stressful or more challenging environmental circumstances (i.e., perpetual flight or fight response). Such adaptation may be metabolic costly to maintain which ultimately shifts the CAB profile towards one of either high-SNS/low-PNS or one of low-SNS/low-PNS. However, empirical studies are lacking to determine the extent to which CAB can differentiate young children with DBDs versus TD.

The current study extends work examining the underlying physiological dysregulation present among children with DBDs by examining the extent to which CAB reactivity measures collected during ER and EF tasks differentiates children with and without DBDs. We expected children with DBDs to have lower CAB reactivity (indicative of lower PNS

relative to SNS activation) across ER and EF tasks relative to typically developing (TD) children.

Methods

Participants

The current study was conducted at a large urban university in the southeastern region of the United States with a predominately Hispanic/Latino population. Families were recruited from local preschools and mental health agencies via brochures, open houses, and online ads. DBDs were assessed through a combination of parent structured interview (Computerized-Diagnostic Interview Schedule for Children; Shaffer et al., 2000) and parent and teacher ratings of symptoms and impairment (Disruptive Behavior Disorders Rating Scale, Impairment Rating Scale; Fabiano et al., 2006) as is recommended practice. Dual Ph.D. level clinician review was used to determine diagnosis and eligibility. Parents of children in the TD group had to have endorsed less than four ADHD symptoms (across either Inattention or Hyperactivity/Impulsivity according to the DSM-5), less than four Oppositional Defiant Disorder (ODD) symptoms and indicated no clinically significant impairment (score below 3 on the impairment rating scale). All participants were also required to be enrolled in school during the previous year, have an estimated IQ of 70 or higher, and have no confirmed history of an autism spectrum disorder diagnosis.

The final sample consisted of 245 young children (Mean age = 5.44 yrs., SD = .80, 72% male) with 122 meeting criteria for a DBD diagnosis (Mean age = 5.50, SD = .74, 76% male; 73% met criteria for ADHD and ODD/CD while 27% only met criteria for ADHD) and 123 TD children (Mean age = 5.39, SD = .85, 68% male). In terms of children's race, 87.8% of the sample was white, 6.1% Black/African American, 2.4% Asian, and 3.7% Biracial. The sample was predominantly Hispanic/Latinx (82.4%) in terms of child ethnicity and bilingual (60.8%). Family marital status of the sample was predominantly married (73.9%) followed by single-parent household (18.8%) and living with a partner (7.3%). In terms of parental education, 66.5% had a college degree or higher, 25.4% had some college or associate degree, and 8.1% had only a high school degree or less. Mothers were predominantly the reporters on questionnaires (86.1%).

Study Design and Procedures

This study was approved by the university's Institutional Review Board. All families participated in a one-time assessment, which included completion of the ADHD, ODD and CD modules on the C-DISC (Shaffer et al., 2000) and various questionnaires regarding their children's behavioral functioning. Children also completed a series of tasks in the laboratory while wearing a total of seven electrodes that were attached to an ambulatory MindWare Mobile. All families received up to \$300 for completing the assessment and other required visits as part of the larger study.

For the *baseline* condition, children watched a 5-minute neutral movie clip while sitting quietly (Calkins et al., 2007). Next, children participated in a series of lab tasks, in the same order, designed to measure EF and ER performance: Conners Kiddie Continuous

Performance Test, Flanker task, Dimensional Change Card Sort task, I'm Not Sharing/Candy-Task, Impossibly Perfect Circles, and Head-Toes-Knees-Shoulders task. Children were provided snacks and coloring breaks between tasks to avoid any carry-over effects between tasks.

ER Tasks

Frustration Task#1. Children participated in a 5-minute frustration task adapted from the Lab-TAB (Goldsmith & Rothbart, 1996): *I'm Not Sharing/Candy-Task*. In this task, the experimenter divided candy unevenly between themselves and the child, eventually taking all the child's candy and eating it.

Frustration Task#2. In the *Impossibly Perfect Circles* task (4 minutes), children are asked to draw circles repeatedly and are criticized (e.g., too large, too small) after each attempt (Goldsmith & Rothbart, 1996). Tasks were discontinued if the child became highly distressed or cried for more than 30 seconds. If the child was not highly distressed, the task was terminated after 3 minutes and 30 seconds, in which the child was praised for their effort and given a small prize from a treasure chest (e.g., stickers, pencils, candy).

EF Tasks: As part of the NIH Toolbox Cognition Battery, children completed the *Flanker task* (Mullane et al., 2009) and the *Dimensional Change Card Sort* (DCCS) (Zelazo, 2006). The Flanker task requires children to inhibit visual attention to irrelevant stimuli, while also performing a stimulus conflict task. During the DCCS task children are required to sort a series of bivalent cards according to the presented dimension (e.g., color and shape). The first trial is based on one dimension, and then the second trial is based on the other. The third phase includes both dimensions, which change item by item. Both the Flanker and DCCS are well validated tasks with young children (Weintraub et al., 2013; Zelazo et al., 2013). Task time across the Flanker and DCCS task was 5–7 minutes each.

Children also completed the *Conners Kiddie Continuous Performance Test* (K-CPT; Conners, 2006), which is a computerized task that assesses attention deficits in young children. During the K-CPT, a series of recognizable pictures are displayed on a computer screen (e.g., soccer ball, house, boat, car). The child is instructed to press the space bar every time they see an image that is not a soccer ball. The task run time is 7.5 minutes, which includes 5 blocks, each containing a 20-trial subblock of 1.5s inter-stimulus intervals and a 20-trial subblock of 3s inter-stimulus intervals.

Lastly children participated in the *Head-Toes-Knees-Shoulders task* (HTKS; Ponitz et al., 2009). The HTKS is a widely used and psychometrically strong task that assesses multiple aspects of EF in young children ages 4 to 7 (Graziano et al., 2015; McClelland et al., 2014; Ponitz et al., 2009). During the HTKS task, children are presented with a set of behavioral rules (i.e., “touch your head” and “touch your toes”) and instructed to perform the opposite behavior (i.e., “touch your head means touch your toes” and “touch your toes means touch your head”) across ten test trials. Children are then asked to switch the rules when presented with two new conflicting behavioral responses (i.e., “touch your knees” and “touch your shoulders”) and in the final trial, all four behavioral rules are changed. Task time was 5–7 minutes.

Measures

Physiological Acquisition

Respiratory Sinus Arrhythmia (RSA) and Pre-ejection Period (PEP). Following standard guidelines (Berntson et al., 1997; Bar-Haim et al., 2000), RSA and PEP data were collected using the MindWare acquisition system (MindWare Technologies, Inc., Gahanna, OH). Specifically, electrocardiography (ECG) and impedance cardiograph (ICG) data were collected via a wireless/mobile device in which each child was fitted with disposable silver/silver-chloride electrodes: The electrodes for the ECG configuration were placed at the right collar bone and the tenth-left rib with the tenth-right rib serving as the ground electrode. Four additional electrodes were placed for the ICG configuration: two voltage electrodes were placed below the suprasternal notch and xiphoid process, and two current electrodes were placed on the child's back (approximately 3 to 4cm above and below the voltage electrodes). ECG and ICG data were recorded throughout all tasks.

RSA, an index of parasympathetic activity, was derived by using spectral analysis in 30 s epochs by extracting the high frequency component of the R-R peak time series (Berntson et al., 1997). Time series were detrended and submitted to a Fourier transform. The high frequency band (in ms^2) was set over the respiratory frequency band of 0.24 to 1.04 Hz, which is the recommended range for children. Respiratory rates were derived from the impedance cardiogram (ICG; Z0) ensuring that the signals remained within analytical bandwidth. PEP, an index of sympathetic activity, was derived from ECG and ICG in 30s epochs, using MindWare Impedance Cardiography V.3.1. PEP was indexed as the time interval in milliseconds from the onset of the Q-wave to the B point of the dZ/dt wave (Berntson et al., 2004). Trained staff visually scanned the data and when appropriate manually removed and adjusted standard artifacts (e.g., misidentified R peaks) using MindWare® Heart Rate Variability Software V.3.1 and/or the MindWare Impedance Software.

Cardiac Autonomic Balance (CAB): RSA and PEP data across 30-s epochs for baseline and ER and EF tasks were averaged to obtain respective RSA and PEP scores. RSA and PEP reactivity scores were computed as the difference between scores from each task and the baseline. Hence, negative values were indicative of PEP shortening (i.e., increased SNS activity) and RSA withdrawal (i.e., reduced PNS activity). Following Berntson et al.'s (2008) procedure, RSA and PEP reactivity scores were first normalized by calculating their individual z-scores, given the differences in measurement scaling. PEP scores were then multiplied by -1 to invert the negative association to a positive one (higher PEP would then indicate greater sympathetic activity). To calculate the balance of parasympathetic to sympathetic activation, CAB reactivity was computed using the following formula: $\text{CAB} = \text{RSA}_z - (-\text{PEP}_z)$. Greater CAB values indicate greater parasympathetic reactivity relative to sympathetic reactivity, whereas lower negative CAB values indicate greater sympathetic reactivity relative to parasympathetic activity. CAB was calculated during the 5-minute baseline condition along with the six ER and EF tasks: the two frustration tasks (I am not sharing candy, Impossible Circle), KCPT, Flanker, DCCS, and HTKS task.

Data Analysis Plan

All analyses were conducted using the Statistical Package for the Social Sciences version 27 (SPSS 27). During physiological data acquisition, excessive artifacts due to movement or hardware malfunction resulted in some unusable data. The percentage of missing data for RSA and PEP physiological measures ranged from 4.49–13.46% across tasks (i.e., baseline, frustration tasks, HTKS, KCPT, Flanker and DCCS). Multiple imputation procedures with 20 iterations were conducted to address such missing data across all analyses (MacKinnon et al., 2002). Two-factor mixed effects analysis of variance were conducted to examine a) changes in the physiological measures across tasks (within-subjects effects), b) potential diagnostic group (i.e., DBD vs. TD) differences (between-subjects effects) and group by task differences on the physiological measures. Given that initial levels of physiological measures can influence the degree of reactivity (Graziano & Derefinko, 2013), all physiological reactivity analyses included baseline levels as covariates.

Results

Descriptive Statistics

There were no differences in child sex, age, ethnicity, and parental education, between groups (see Table 1). Thus, no demographic covariates were included in our analyses. First, there was a significant within subject task effect, $F(6, 1458) = 46.22, p < .001$ and task by group effect, $F(6, 1458) = 2.19, p = .041$ as it relates to change in RSA across tasks. Pairwise comparisons indicated a significant decrease in RSA from baseline to all tasks across both groups (p 's range from .029 to $< .001$) with children in the DBD group experiencing greater decreases in RSA versus TD children. Second, there was a significant within subject task effect, $F(6, 1458) = 3727.083, p < .001$ as it relates to change in PEP across tasks. No task by group effect was found, $F(6, 1458) = 1.39, p = .216$. Pairwise comparisons indicated that two tasks (KCPT and HTKS) showed a significant change in PEP from baseline such that there was a lengthening of PEP during the KCPT ($p = .002$) suggesting a decrease in SNS arousal but a shortening of PEP during the HTKS ($p = .003$), suggesting an increase in SNS arousal.

RSA and PEP Reactivity Results

First, it is important to note that there were no significant differences in baseline RSA or PEP across groups. As it relates to RSA, while there was not a significant overall between-subjects effect across tasks, $F(1, 242) = 2.32, p = .129$, children in the DBD group had significantly greater RSA withdrawal (indicative of reduced PNS activity) during the KCPT and HTKS tasks relative to TD children. On the other hand, there was a significant between-subjects effect for PEP reactivity across tasks, $F(1, 242) = 4.68, p = .032$. As seen in Table 2, follow-up pairwise comparisons indicated that children in the DBD group had lower PEP reactivity (PEP shortening indicative of increased SNS activity) during the Candy frustration task and Flanker task relative to TD children who had PEP lengthening (indicative of decrease in SNS activity). Children in the DBD group also had lower PEP reactivity (lower positive scores indicating lengthening of PEP) during the KCPT task relative to TD children, who had significantly greater lengthening of PEP (indicative of greater decreases in SNS activity).

CAB Reactivity Results

As seen in Table 3, there were no significant differences in baseline CAB between TD children and those with DBD. On the other hand, there was a significant between-subjects effect for CAB reactivity across tasks, $F(1, 242) = 7.15, p = .008$. Follow-up pairwise comparisons indicated significant differences in 4 out of the 6 tasks as children with DBD had lower CAB reactivity in the Candy frustration task ($d = -0.36$), Flanker task ($d = -0.28$), HTKS ($d = -0.27$), and KCPT ($d = -0.38$), compared to TD children (see Figure 1).

Discussion

The current study focused on the usefulness of an *integrative* measure of PNS and SNS (i.e., CAB) to further understand the underlying physiological dysregulation present among children with DBDs. First, it is important to point out that there were no significant differences in baseline CAB between children with DBDs and those in the TD group. While this represents the first study to find such null differences in baseline CAB, others have found similar null findings as it relates to physiological functioning at *baseline* including RSA and PEP in older children with DBDs versus TD (Leaberry et al., 2018; Musser et al., 2011). In fact, our study with younger children with DBDs also found similar null differences in baseline RSA and PEP. Hence, it appears that the ANS of children with DBDs can effectively support homeostasis by promoting rest and restorative behaviors similar to children in the TD group when the context is *low* demand/stress.

On the other hand, children with DBDs had lower CAB reactivity, relative to children in the TD group, in the context of four out of six demanding/challenging ER and EF tasks. Children with DBDs' negative CAB values indicate a physiological profile of greater SNS reactivity while children in the TD group's positive CAB values indicate a physiological profile of greater PNS reactivity. As reviewed by Quigley & Moore (2018), normative autonomic maturity is marked by a shift from high SNS/low PNS in gestation/infancy towards one of low SNS/high PNS in early childhood and adulthood. Hence, our results show that children with DBDs appear to be lagging relative to TD children in terms of their physiological regulation maturity as they are still relying more heavily on increasing SNS during challenging/demanding states.

Importantly, children with DBDs' physiological regulation profile of relying more on SNS vs. PNS occurred across both ER and EF tasks. Prior work on children with DBDs' physiological functioning had primarily used ER related tasks or those related to motivation/rewards and had found blunted/low PEP reactivity and/or dampened/low RSA reactivity relative to TD children (Tenenbaum et al., 2018). On the other hand, among older children with ADHD, emerging work suggests that social tasks may induce a greater physiological response compared to traditional frustration tasks (Bellato et al., 2024; McQuade & Breaux, 2017). Future research should examine physiological functioning during ER tasks that tap into different functional domains (i.e., emotional and social functioning) longitudinally to determine when this autonomic maturity shift occurs.

By utilizing CAB and the autonomic space model (Berntson et al., 1993) as a way to understand both RSA and PEP reactivity, our study extends such literature by showing

that this greater SNS reactivity profile among children with DBDs appears to be a combination of shortening of PEP and/or excessive RSA withdrawal (depending on the task) which highlights the value of examining CAB reactivity as an integrative ANS measure. Additionally, very few studies have examined children's physiological regulation during cognitive/EF tasks (Marcovitch et al., 2010; Quas et al., 2006; Ward et al., 2015; Feeney et al., 2023). Fronto-subcortical neural systems involved in EF and ER are feedforward contributors to hypothalamic circuits influencing parasympathetic suppression and sympathetic activation (Nashiro et al., 2022; Thayer et al., 2012), which may partially explain the overlap in the physiological regulation of both ER and EF tasks. Given the well-established ER and EF deficits present in children with DBDs (Graziano & Garcia, 2016; Ogilvie et al., 2011), our study demonstrates how a physiological regulation profile of low CAB occurs similarly across these domains.

Regarding clinical implications, recent work has increasingly focused on precision medicine which seeks to identify specific biological indicators that can inform diagnostic conceptualization and personalized treatment (Buitelaar et al., 2022). For example, research has linked reduced white-matter connectivity in specific brain regions and activity to symptoms and treatment-related changes in anxiety and depression (Dickey et al., 2023; Uchida et al., 2021). However, less work has been done within the externalizing literature among younger children in terms of whether biological measures can incrementally predict functional impairments, diagnoses, and/or treatment response (Connaughton et al., 2022; Öztekin et al., 2021). Identifying reliable physiological indicators of DBDs could enhance diagnostic accuracy by differentiating between overlapping symptom presentations and informing more targeted interventions. While our findings contribute to such emerging literature, it is important to acknowledge the modest effect sizes. Given the additional cost and time required to implement physiological assessments in a clinical setting, further research is needed to establish their practical utility (e.g., cost-effectiveness). Nonetheless, future work should continue to explore whether these physiological indicators could help predict differential diagnoses and treatment response, ultimately advancing a more individualized approach. In terms of study limitations, given that the majority of our DBD sample had comorbid ADHD and ODD/CD, we did not have sufficient power to examine subgroups within the DBD sample. For example, at the behavioral level, there is some research to suggest that children with ADHD, predominantly inattentive type, have different etiology compared to those with ADHD combined type, as well as comorbid ODD/CD (Luo et al., 2019). Thus, future work can determine whether the low CAB reactivity profile is also found with a purer ADHD group. Additionally, we did not have a reward/motivation-based task or positive affect related task which have previously been found to relate to ANS dysfunction among children with DBDs, particularly children with ADHD (Tenenbaum et al., 2018). However, such work within the reward/motivation and positive affect domain have focused on either RSA and/or PEP alone and thus it remains unclear how CAB during these tasks may differentiate children with DBDs and/or relate to their performance. Finally, a large percentage of the current sample identified as Hispanic/Latinx (82.4%), therefore limiting the generalizability of our findings to non-Hispanic/Latinx populations. However, given that few studies on physiological functioning include ethnically and racially diverse samples (Feeney et al., 2023; Morris et al., 2020), this study contributes to the knowledge

of identifying an integrative physiological indicator for emotion and executive dysfunction in one of the largest growing and understudied group in the United States (La Greca, Silverman, & Lochman, 2009).

In summary, this represents the first study, to our knowledge, to show how an integrative physiological measure in CAB reactivity across both ER and EF tasks can differentiate young children with DBDs from those considered TD. Given such physiological overlap along with established overlaps in neural circuitry, it seems that early interventions should target a broader self-regulation construct that inherently will include both ER and EF processes. Future work should also examine the extent to which CAB reactivity predicts and/or perhaps is malleable to early intervention programs such as the Summer Treatment Program for Pre-Kindergartners (STP-PreK), which have documented behavioral improvements in children with DBDs self-regulation skills, including ER and EF measures (Graziano & Hart, 2016). It may be the case that long term treatment success for children with DBDs is more likely to occur for those who have improved their physiological self-regulation skills (i.e., CAB). In turn, we may be able to provide more precise and/or additional long-term intervention for children who continue to show deficits in SNS and PNS functioning.

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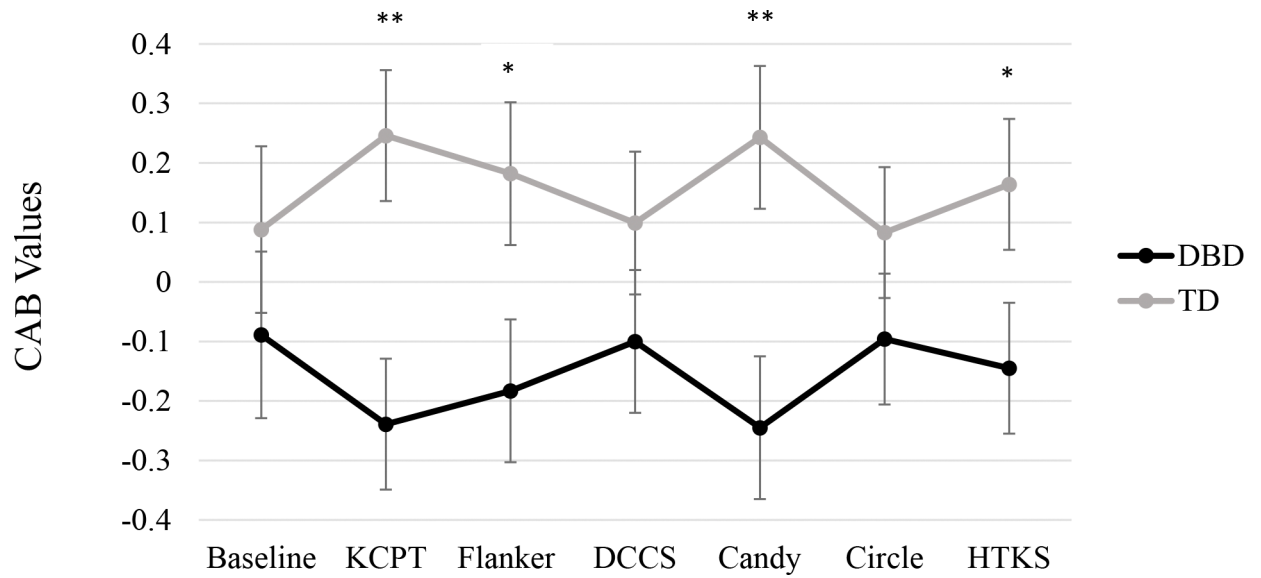


Figure 1. CAB reactivity scores across tasks by diagnostic group

Note. ** $p < .01$, * $p < .05$. DBD = disruptive behavior disorders; TD = typically developing; CAB = cardiac autonomic balance, HTKS = Head-Toes-Knees-Shoulder task; Flanker = Flanker task, DCCS = Dimensional Change Card Sort; Candy = I'm Not Sharing/Candy Frustration Task, Circle = Impossible Circles Frustration Task, KCPT = Conners Kiddie Continuous Performance Test.

Table 1.**Demographic Variables**

	Total Sample (n = 245)	TD (n = 123)	DBD (n = 122)
Demographic Variables			
Child sex (% male)	71.8	67.5	76.2
Mean Child age (SD)	5.44 (.80)	5.39 (.85)	5.50 (.74)
Child Race (%)			
White	87.8	86.9	88.5
Black/African American	6.1	4.9	7.4
Asian	2.4	4.1	0.8
Multiracial	3.7	4.1	3.3
Child Ethnicity (%)			
Hispanic/Latino	82.4	82.1	82.8
Non-Hispanic/Latino	17.6	17.9	17.2
Maternal Education (%)			
Some High School	2.0	3.3	0.8
High School Diploma/GED	6.1	6.5	5.7
Some College	12.7	8.9	16.4
Associate's Degree	12.7	13.8	11.5
Bachelor's Degree	31.0	30.9	31.1
Advanced Degree	35.5	36.6	34.4

Table 2.**RSA and PEP results**

	DBD (n = 122)	TD (n = 123)		
Variable	Mean (SE)	Mean (SE)	p	Cohen's d (C.I.)
Baseline				
RSA-BL	6.58 (.11)	6.53 (.11)	.768	0.04 (−0.21, 0.29)
PEP-BL	75.87 (1.00)	78.25 (.99)	.092	−0.22 (−0.47, 0.04)
Emotion Regulation Tasks				
RSA-Candy	6.09 (.10)	6.24 (.10)	.307	−0.13 (−0.38, 0.12)
PEP-Candy	75.18 (.97)	79.41 (1.04)	.005	−0.36 (−0.62, −0.11)
RSA-R-Candy	−.481 (.08)	−.305 (.07)	.095	−0.21 (−0.46, 0.04)
PEP-R-Candy	−1.01 (.75)	1.46 (.74)	.020	−0.30 (−0.55, −0.05)
RSA-Circle	6.39 (.10)	6.36 (.10)	.845	0.03 (−0.22, 0.28)
PEP-Circle	75.67 (.96)	78.70 (.95)	.025	−0.29 (−0.54, −0.04)
RSA-R-Circle	−.182 (.07)	−.179 (.07)	.974	0.00 (−0.25, 0.25)
PEP-R-Circle	−.531 (.62)	.771 (.62)	.141	−0.19 (−0.44, 0.06)
Executive Functioning Tasks				
RSA-Flanker	6.14 (.10)	6.17 (.10)	.861	−0.02 (−0.27, 0.23)
PEP-Flanker	75.19 (.97)	79.13 (.97)	.004	−0.37 (−0.62, −0.11)
RSA-R-Flanker	−.432 (.06)	−.373 (.06)	.517	−0.08 (−0.33, 0.17)
PEP-R-Flanker	−1.05 (.68)	1.24 (.68)	.019	−0.30 (−0.55, −0.05)
RSA-DCCS	6.12 (.10)	6.11 (.10)	.899	0.02 (−0.23, 0.27)
PEP-DCCS	75.72 (.96)	78.80 (.95)	.024	−0.29 (−0.54, −0.04)
RSA-R-DCCS	−.447 (.07)	−.435 (.07)	.908	−0.01 (−0.27, 0.24)
PEP-R-DCCS	−.553 (.70)	.940 (.69)	.131	−0.19 (−0.44, 0.06)
RSA-KCPT	6.09 (.11)	6.22 (.11)	.359	−0.12 (−0.37, 0.13)
PEP-KCPT	76.49 (.98)	79.96 (.97)	.012	−0.32 (−0.57, −0.07)
RSA-R-KCPT	−.488 (.06)	−.313 (.06)	.047	−0.26 (−0.51, 0.00)
PEP-R-KCPT	.425 (.51)	1.90 (.51)	.041	−0.26 (−0.51, −0.01)
RSA-HTKS	5.60 (.10)	5.84 (.10)	.077	−0.23 (−0.48, 0.03)
PEP-HTKS	74.06 (.93)	75.93 (.93)	.157	−0.18 (−0.43, 0.07)
RSA-R-HTKS	−.969 (.08)	−.699 (.08)	.021	−0.30 (−0.55, −0.04)
PEP-R-HTKS	−2.47 (.82)	−1.68 (.82)	.495	−0.09 (−0.34, 0.16)

Note. SE = standard error; CI = 95% confidence interval; DBD = disruptive behavior disorders; TD = typically developing; BL = Baseline; PEP-R = Pre-ejection period reactivity; RSA-R = respiratory sinus arrhythmia reactivity; Negative PEP-R values are indicative of PEP shortening (i.e., increased SNS activity) and negative RSA-R values are indicative of RSA withdrawal (i.e., reduced PNS activity). HTKS = Head-Toes-Knees-Shoulder task; Flanker = Flanker task, DCCS = Dimensional Change Card Sort; Candy = I'm Not Sharing/Candy Frustration Task; Circle = Impossible Circles Frustration Task, KCPT = Conners Kiddie Continuous Performance Test.

Table 3.

CAB results

	DBD (n = 122)	TD (n = 123)		
Variable	Mean (SE)	Mean (SE)	p	Cohen's d (C.I.)
Baseline				
CAB-BL	-.089 (.14)	.088 (.14)	.353	-0.12 (-0.37, 0.13)
Emotion Regulation Tasks				
CAB-Candy	-.245 (.12)	.243 (.12)	.005	-0.36 (-0.61, -0.10)
CAB-Circle	-.096 (.11)	.083 (.11)	.255	-0.15 (-0.40, 0.10)
Executive Functioning Tasks				
CAB-Flanker	-.183 (.12)	.182 (.12)	.031	-0.28 (-0.53, -0.02)
CAB-DCCS	-.100 (.12)	.099 (.12)	.223	-0.16 (-0.41, 0.09)
CAB-KCPT	-.239 (.11)	.246 (.11)	.003	-0.38 (-0.64, -0.13)
CAB-HTKS	-.145 (.11)	.164 (.11)	.039	-0.27 (-0.52, -0.01)

Note. CAB reactivity analyses controlled for baseline levels of CAB. SE = standard error; CI = 95% confidence interval; DBD = disruptive behavior disorders; TD = typically developing; BL = Baseline; CAB = cardiac autonomic balance; HTKS = Head-Toes-Knees-Shoulder task; Flanker = Flanker task, DCCS = Dimensional Change Card Sort; Candy = I'm Not Sharing/Candy Frustration Task, Circle = Impossible Circles Frustration Task, KCPT = Conners Kiddie Continuous Performance Test.